Chilling in the sunshine

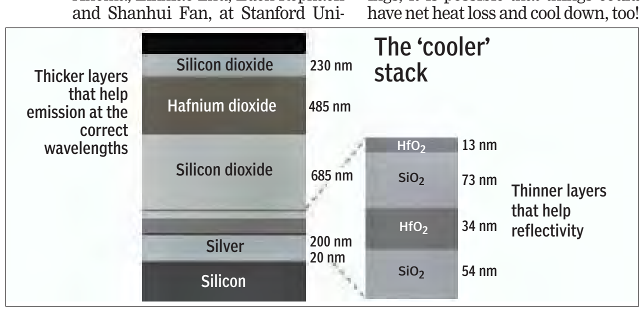
A SURFACE THAT CAN LOSE HEAT EVEN WHILE THE SUN SHINES MAY BE AN ECONOMICAL WAY TO STAY COOL, WRITES S ANANTHANARAYANAN

Airconditioning is one of the greatest comforts of modern times but also a villain that accounts for a large share of CO_2 emissions. With rising global temperatures, airconditioning would become a greater necessity, both for comfort as well as to preserve food materials, but it would also be a first candidate to curtail, to reduce electricity use.

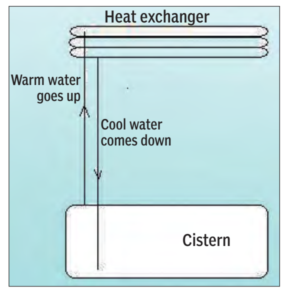
But just as there are ideas of using the large reserve of geothermal heat buried within the earth to save use of fossil fuel, there could be a way to bring about cooling by tapping the icy chill of outer space and, hence, save the energy costs of refrigeration. Aaswath P Raman, Marc Abou Anoma, Linxiao Zhu, Eden Rephaeli and Shanhui Fan, at Stanford University, report in the journal *Nature* what amounts to an *optical umbrella* that allows things to cool down through what could be called a *radiation drainpipe*.

There have been earlier ideas of using the coolness of the night to chill things for the day that follows. One way was a rooftop heat exchanger, which would cool and store water through the night for use during the hot daytime. There has even been the real "radiative" refrigerator, where the radiator surface lost heat at the eight to 13 micrometre wavelength, which the atmosphere does not absorb — which means the heat was sent out to outer space — during the night. But such methods could not work in the daytime as the radiating surface would be warmed, many times more than it cooled, by the sun. But the Stanford team reports success, for the first time, of an arrangement that cools down nearly five degrees Celsius, while standing in direct sunlight!

The principle is that all things cool by radiation but things on the surface of the earth also gain heat, through sunlight and from the surroundings, which are warmed both by the sun and by the heat that the surface radiates. But if the surface reflected most of the incident light and the heat radiated by the surface were beamed out of the atmosphere, instead of warming the surroundings, it is possible that things could have net heat loss and cool down, too!



But as the energy radiated by objects at normal temperatures is low, and readily absorbed, and the incident energy that comes from the sun is high, the conditions for net cooling are difficult to satisfy. The reflectivity, for one, needs to be over 94 per cent. At the same time, the radiation from the surface needs to be strong in the narrow window of wavelengths that can pass through the atmosphere. This combination has been difficult to implement — attempts with metallic foil reflectors to keep solar radiation off normal thermal emitters have not been successful in causing cooling while in the sunlight. And, finally, the arrangement needs to be protected from the surroundings; anything in contact with the cooler device will warm up in the sun and make sure the cooler device does the same.



The paper in *Nature* says that there has been a concept of how this could be done with the help of two-dimensional nanostructures to manipulate radiation and attain the required reflectivity and emissivity. But this proposed design involved a complex fabrication technique of very fine-scale components. The present design, which has also been realised in practice, uses one-dimensional film architecture that can more easily be scaled up. The cooler itself is also installed in an apparatus that protects it from external heat and the actual temperature drops, while in sunshine.

The reflector-emitter consists of seven alternating layers of the materials hafnium dioxide and silicon dioxide, mounted on a 200-nm silver base, itself mounted on a silicon wafer. The thickness of the layers of the oxides, which have high and low refractive indices respectively, were arrived by iterative optimisation. The bottom four layers are thinner and they bring about the best reflectivity over the whole solar spectrum.

The top three layers are thicker and are primarily responsible for the selective emissivity. Through a combination of material properties and optical effects, silicon dioxide emits strongly at the nine µm wavelength and hafnium oxide does the same for nine-13 µm wavelengths. The seven layers together, then, make for very high reflection, which translates to very low absorption of solar radiation and also for the highest emission of radiation in wavelengths that the atmosphere does not absorb. The effect is thus as if the cooler stack is both not warmed by sunlight and also free to emit radiation, arising from its own temperature, clean out into space. The hafnium dioxide material can also be replaced by the cheaper titanium dioxide.

The housing of the cooler stack takes care of the entry of heat from the surroundings. The silicon wafer, with the radiative cooling stack, is mounted on a polystyrene holder, which is supported by a clear acrylic box, fixed to a wooden frame. Just over the cooler stack is a thin polyethylene film, transparent to Infra Red radiation, and acts as a windshield. The cooler device is thus suspended in an air pocket and the whole arrangement is placed in the middle of a large rooftop to make sure that the support of the cooler do not get warmed by external radiation. Experimental trials of the reflectivity and the emissivity of the device show 97 per cent reflection through the solar spectrum, 300 nm to four µm, and strong, selective emission within the atmospheric window of eight-13 µm.

The device, which is called *passive cooling*, was demonstrated on a clear day in Stanford shortly before 10 am on the roof of a building.

Immediately after the sample was exposed to sunlight, its temperature drops four-five degrees Celsius below the ambient. "This is a key signature of radiative cooling and a counterintuitive: we typically think of surfaces increasing their temperature when removed from the shade and exposed to the sun during the day," say the researchers in the paper.

The sample in the trial was kept out in the sun for several hours and it steadily maintained a temperature four-five degrees Celsius below the ambient. Trials of watching the temperature of the sample as heat was externally supplied allowed measurement of the cooling of the sample, at about 40 Watts per square metre.

This is substantial cooling and the method compares well with alternatives like solar panels that power cooling systems. There is also scope to improve the design to attain an output of 100W per square metre.

"Improving building efficiency with a view towards reducing the need for active cooling has taken on renewed urgency on our warming planet, where the increase in carbon emissions caused by airconditioning is predicted to be faster than the decline in emissions from reduced heating. In off-grid areas of the developing world, achieving radiative cooling during the daytime offers the opportunity to enable electricity-free cooling for critical needs like long-term food and medical supply storage.

"More broadly, our results point to the largely unexplored opportunity of using the cold darkness of the universe as a fundamental renewable thermodynamic resource for improving energy efficiency here on earth," the authors say in the paper.

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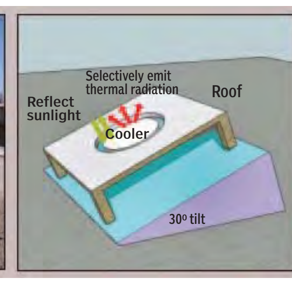

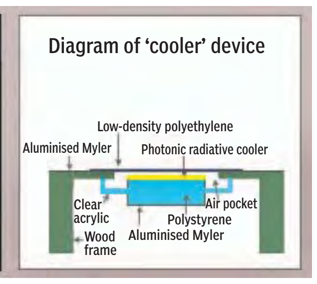

LAWS OF INHERITANCE

TAPAN KUMAR MAITRA EXPLAINS SEXUAL REPRODUCTION, MEIOSIS AND GENETIC RECOMBINATION

Asexual reproduction is based on mitosis and produces offspring that are genetically identical (or nearly so) to the single parent. Sexual reproduction, on the other hand, involves two parents and leads to a mixture of parental traits in the offspring.

Sexual reproduction allows populations to adapt to environmental changes, enables desirable mutations to be combined in a single individual and promotes genetic flexibility by maintaining a diploid genome.

The life cycle of every sexually reproducing eukaryotic species includes both haploid and diploid phases. Haploid gametes are generated by meiosis and fuse at fertilisation to restore the diploid chromosome number. Meiosis consists of two successive cell divisions without an intervening duplication of chromosomes. During the first meiotic division, homologous chromosomes separate and segregate into the two daughter cells. During the second meiotic division, sister chromatids separate and four haploid daughter cells are produced.

In addition to reducing the chromosome number from diploid to haploid, meiosis differs from mitosis in that homologous chromosomes synapse during prophase of the first meiotic division, thereby allowing crossing over and genetic recombination between nonsister chromatids.

Mendel's laws of inheritance describe the genetic consequences of chromosome behaviour during meiosis, even though chromosomes had not yet been discovered at the time of Mendel's experiments. According to these laws, maternal and paternal alleles segregate into different gametes during meiosis and the alleles of genes located on separate chromosomes assort independently of one another. The enormous genetic variability among an organism's gametes arises in part from the independent assortment of chromosomes during anaphase I and in part from the recombination that occurs during prophase I. The frequency of recombination between genes located on the same chromosome is a measure of the distance between the two genes and can, therefore, be used to map their chromosomal locations.

In addition to occurring during meiosis in eukaryotes, homologous recombination is also observed in viruses (during co-infection) and when DNA is transferred into prokaryotic cells by transformation, transduction or conjugation. The mechanism of recombination involves breakage-and-exchange between DNA molecules that exhibit extensive sequence homology. Recombination is sometimes accompanied by gene conversion or the formation of DNA molecules whose two strands are not completely complementary to one another. These phenomena can be explained by recombination models involving the formation of Holliday junctions, which are regions of single-strand exchange between double-stranded DNA molecules.

The development of recombinant DNA technology has made it possible to combine DNA from any two (or more) sources into a single molecule of recombinant DNA. Combining a gene of interest with a plasmid or phage cloning vector allows the gene to be cloned (amplified) in bacterial cells. In this way, large amounts of specific genes or their protein products can be prepared for research or practical purposes. Recombinant DNA technology has made possible the detailed analysis and manipulation of eukaryotic genomes, including the human genome. At the same time, practical applications of this technology have the potential to revolutionise modern medicine and agriculture.

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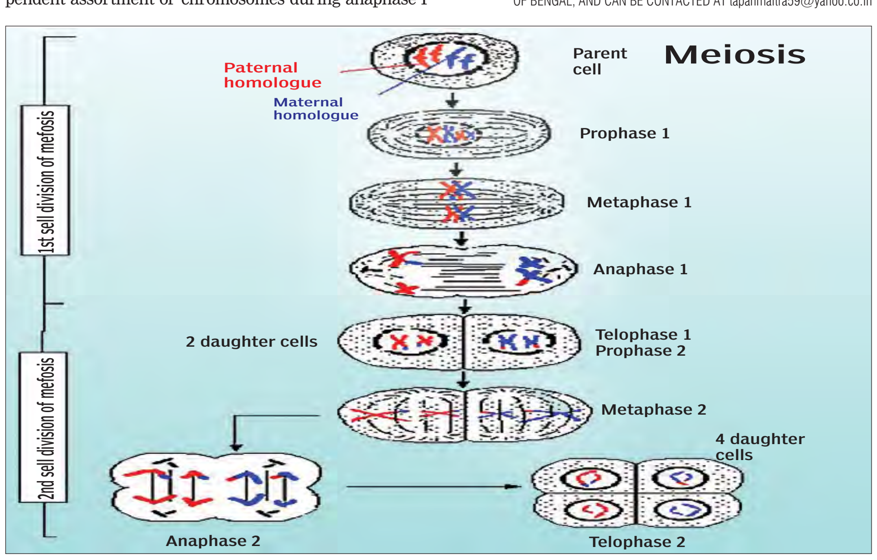

'Cities for the people'

KATE HAWLEY EXAMINES HOW URBAN AREAS ARE EVOLVING TO BE SUSTAINABLE – THEIR CHALLENGES, TRENDS AND SOLUTIONS

Already 54 per cent of the world's population lives in urban regions and projections suggest this will keep increasing until at least 2050. The shift from a rural- to an urban-dominant globe signals more strongly than ever the need to transform how cities develop.

Architects, engineers, urban planners, civil society and policy makers face the challenges of creating sustainable, healthy, "smart", "green", adaptive, inclusive, productive, safe, flexible and resilient cities. These are just a few of the characteristics that will help urban centres thrive in the face of rising populations, growing informal settlements, pollution and environmental degradation, often combined with poor governance and service provision.

Some cities around the world are pioneering the way, helping the development community envision alternatives to mainstream models of urban development, and focusing on creating environmentally friendly "cities for the people", rather than economic growth.

Research and thinking about sustainable cities began in the 1980s but the term sustainability entered the global dialogue in the 1990s, introduced by the World Commission on Environment and Development. In particular, the crucial role that environmental and social dimensions of human economic activities play in creating a better world surfaced during the Earth Summit in Rio in 1992. Influencing those discussions, an agenda-changing report, authored by the International Union for Conservation of Nature, World Wide Fund for Nature and the UN Environment Programme highlighted how humans construct landscapes at the expense of the environment — and urged a focus on sustainable development.

In the late 1990s David Satterthwaite, a key expert in the field, put forward characteristics of a "successful" city. He argued that a city needed to ensure healthy living and working environments and provide infrastructure for basic services such as clean water, sanitation and waste management. He also argued that — in keeping with the basic principles of sustainable development — a city needed to exist in an equilibrium with environmental systems, for example by ensuring balanced water tables and low environmental pollution.

Down the years, discussions on urban sustainability began to include spatial design and planning (known as "urban form"), and making cities "user-friendly" through transport systems that were accessible to all. Through this, definitions of urban form became more detailed — referring to dense, compact, mixed-use spaces with integrated public transportation, environmental policies and management.

In 2005, the World Summit on Social Development introduced the concept of economic, social and environmental "pillars" of development. Now, as the post-2015 agenda develops, negotiations are underway to secure a spot for an urban Sustainable Development Goal that will ensure green, well-planned, inclusive, resilient, productive, safe and healthy cities.

The world's urban population stands at 3.9 billion, more than half of them living in "small" cities with less than 500,000 people, while approximately 12 per cent reside in megacities (of over 10 million). By 2050, an estimated two-thirds of the world's population — about 6.2 billion people — will live in urban centres. In other words, we will see urban growth (rising urban populations) and urbanisation (a higher proportion of people will live in cities).

African and Asian cities have grown faster since 2000 than cities in any other part of the world. And more than half of these continents' populations are expected to live in cities by 2050. And by then, India, China and Nigeria alone are expected to add 2.5 billion people to their urban areas.

Interestingly, the fastest growing urban settlements are not the megacities that so often hit the headlines, but the medium-sized and smaller cities that house less than one million inhabitants. By 2025, megacities will have accounted for just 10 per cent of global urban growth. Medium and large cities will contribute to more than half of global growth, followed closely by small cities. Integrative design is also starting to take hold as a way for the developing world to attack challenges that developed countries do not face. This offers opportunities to lead with innovation and by including many stakeholders in the process. In India, for instance, a for-profit social enterprise has approached the challenge of water provision. The cost of piping water to every household is expensive, time-consuming and sometimes impossible. Savajal provides solar-powered water "ATMs", which sell safe drinking water to those without access to a citywide system. Initially installed in rural areas, these are now being introduced to Delhi. The dispensers accept smartcards similar to prepaid phone cards and can be accessed 24 hours a day.

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PLUS POINTS

Genomes galore

Two papers published on 27 November in *Science* announced the completion and preliminary analyses of the genomic sequences of 16 species of mosquitoes, including those that are vectors for the malaria parasite. The sequences, which were around 200 million base pairs each, revealed that mosquitoes were rapidly evolving, exhibiting high degrees of gene gains, losses, shuffling and even transmission between closely related species.

"Both papers provide really powerful information on the evolution of different malaria mosquito species," wrote James Logan of the London School of Hygiene and Tropical Medicine in an e-mail. "Comparisons between the (species) are likely to reveal the reason why some mosquitoes are better at transmitting malaria than others, (which is) vital for the future control of malaria," he added.

Each year, hundreds of millions of cases of malaria are reported globally that cause hundreds of thousands of deaths. In 2002, as part of an ongoing effort to understand mosquito biology and ultimately reduce disease transmission, the genome sequence of *Anopheles gambiae* — the major malaria vector of sub-Saharan Africa — was published.

"Having one genome is a great start, but it's not enough," said Nora Besansky, malaria vector researcher at the University of Notre Dame, Indiana, who led the latest sequencing effort. There were about 450 species of *Anopheles* mosquitoes and roughly 60 of them transmitted malaria, but they were not all closely related, Besansky explained. Therefore, she said, "If our interest is in trying to control malaria by targeting the mosquito itself in some way, we need to understand what they (the malaria mosquitoes) all have in common."

RUGH WILLIAMS/*THE SCIENTIST*

Next Turing test

A recently released biopic of Alan Turing (*The Imitation Game*) tells the story of the British mathematician and cryptographer who built a machine to crack the German Enigma code during World War II. But Turing is perhaps best known for his pioneering work on artificial intelligence.

In 1950, he introduced a landmark test of artificial intelligence. In the so-called Turing test, a person engages in simultaneous conversations with both a human and a computer, and tries to determine which is which. If the computer can convince the person it is human, Turing would consider it artificially intelligent.

The Turing test has been a helpful gauge of progress in the field of Artificial Intelligence, but it is more than 60 years old and researchers are developing a successor that they say is better adapted to the field of AI today.

Robot 'elves'

On one of the busiest online shopping days of the year, thousands of bright-orange, pancake-shaped robots buzzg around Amazon's shipping centres, rushing to fill the company's Cyber Monday orders. Last year, Amazon CEO Jeff Bezos announced that he eventually planned to use drones to deliver packages to online shoppers, but while the Federal Aviation

Administration crafts official regulations for the commercial use of drones, the online retail giant has found an intermediate step: flat, wheeled robots that zoom around Amazon's warehouses, carrying seven-foot-tall stacks of books, electronics and toys.

The robots navigate on a grid system made of bar-code stickers stuck to the warehouse floor. The bots know which products to gather by scanning the bar codes as they roll along. The flat robots can slip under shelves full of products, lift them up and transport them back to employees, who then sort out the individual orders. The robots can lift shelves that weigh up to 340 kg, according to the company's website.